SONICALLY-ENHANCED MOUSE GESTURES IN THE FIREFOX BROWSER

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ABSTRACT

The use of the mouse to allow interaction via gestures has attracted much interest recently and the popular FIREFOX web browser has been enhanced by an extension supporting mouse gestures. These gestures reveal an interaction problem: feedback is limited (often only a terse message in the browser's status bar) and navigation errors easily result when the user unknowingly executes a gesture when trying to accomplish some other task (e.g. copying text from a web page). This paper describes an attempt to improve the interaction experience by adding auditory cues to inform the user about the progress and progression of gestural commands. FIREFOX was chosen as it has an open extension architecture that is easily modified. Preliminary trials indicate increased user satisfaction and comprehension when using auditory-enhanced gestures over the non-enhanced gestures.

1. GESTURES

A gesture is "*a mark or stroke that causes a command to execute*" [1]. Gestures are common in mobile interfaces ([2, 3]) as they offer a usable alternative to the keyboard and mouse, though a high recognition accuracy is needed to prevent rejection by users [2, 1].

The most common gestures are driven by a stylus, finger or mouse [1]. Moyle & Cockburn [4] examined mouse gestures for web navigation. They were motivated by usability issues associated with the "back" and "forward" command buttons in a web browser, and demonstrated that simple mouse gestures could be used to decrease the time taken to execute these actions.

1.1. Gestures and Auditory Feedback

The benefits of gestural interaction can be greatly increased when combined with auditory feedback: users utilise both auditory and visual senses when trying to classify and thus understand a gesture [5]. Pirhonen et al [6] designed the TOUCHPLAYER music player for a PDA. This allowed users to operate the player with gestures. Users were presented with auditory feedback in the form of earcons following a gesture being made, which confirmed the command had registered and what the command was. Testing demonstrated that gestures followed by clear auditory feedback were rapidly learnt. The particular use of auditory feedback in systems which utilise gestures is commonly seen as a method of enhancing user learnability [7].

Brewster et al. [3] developed a device which involved gestural interaction using head movements. Here, auditory enhancement was used as a precursor to command selection and not as feedback. A user would hear spatial earcons through headphones, and would make a nodding gesture towards the required command. Results from this study indicated that a limited menu of items showed increased usability when dynamic earcons were coupled with head gestures.

2. AUDIO-ENHANCED GESTURAL INTERACTION IN A WEB BROWSING INTERFACE

There is limited literature dealing specifically with sonically enhanced gestural interaction for web browsing. Moyle and Cockburn [4] investigated forward and back gestures in a web browser (using a technique called *marking menus* - see [8] and [9]). The motivation was to reduce the time taken to carry out navigational operations in a web browser. This is similar to the motivation behind this project, except that we will be looking at user satisfaction rather than speed.

Two important issues associated with designing gestural interaction are [9, 10]:

1. The coordinates of a mouse gesture must change from the start to finish point by a minimum of 35 pixels, otherwise the gesture may be recognised as a simple mouse click.
2. A mouse gesture must be completed within 250 ms. in order to prevent it being recognised as a mouse click or a copy-and-paste-type standard manoeuvre.

These issues manifest themselves in the browsing environment as unrecognised gestures, unwanted gestures, and a level of confusion over what is happening in the interface. It is in this area particularly that a level of auditory feedback might assist in reducing the number of gestural errors and confusion. In their study on implementing auditory enhancements for the MOSAIC browser, Albers & Bergman [11] undertook an informal evaluation into how this feedback affected users. The study was not related specifically to gestures but to mouse interacton in general, however it is still instructive. Albers & Bergman concluded that auditory feedback could be used to confirm user actions without interrupting the visual field. If we relate these findings back to the issue of gesture recognition, we can use the auditory feedback to confirm to the user what they have just done without distracting them visually. This may also help to reduce confusion with gestures as the feedback given can clarify the current situation

In exploring the advantages of Auditory Display in a web environment Maasø [12] suggests sound cues can provide feedback on actions about to be made, as well as already made. Maasø also states that sound is well suited to monitoring background activities while performing other actions. If these ideas are applied to the problems associated with gestures they can further help in increasing usability. By using auditory feedback during an activity as well as following it, a user would be further aware of what action they were currently taking and whether or not it was valid. This type of valid/invalid feedback was also successfully evaluated by Albers & Bergman [11].

2.1. Gesture Identification & Classification

The first step in the design process is to decide which gestures to support. The MOZGEST mouse gesture extension for FIREFOX provides 29 gesture actions. Table 1 shows the most common gestures which are likely to be utilised while browsing, and it is these functions which will be sonically enhanced with earcons. Table 1

Family	*Type*	Function	Mouse Movements
Navigation	*Browsing*	Page Forward	Right
		Page Back	Left
		Load Home Page	Down–Up–Right–Down
	Page Scroll	Scroll Page Up	Right–Up–Down
		Scroll Page Down	Right–Down–Up
	Functions	Open New Window	Down
		Reload Current Page	Up–Down
		Close Window	Right–Left–Right
Tabs	*Browsing*	Next Tab	Up–Right
		Previous Tab	Up–Left
	Functions	New Tab	Up
		Duplicate Tab	Down–Up–Down
Images		Zoom In	Down–Right (over image)
		Zoom Out	Up–Left (over image)
		Hide	Down–Left (over image)
Links		Open In New Window	Down (over link)
		Open In New Tab	Up (over link)

Table 1: Common browsing gestures categorised by family, type, and function

classifies the gestures into families, and further divides some families into function classes. This is done in anticipation of the earcon design. Grouping the gestures in this manner allows a corresponding earcon hierarchy to be constructed.

2.1.1. Earcon Design

The hierarchy of earcons was derived from the classifications given in Table 1. To differentiate each earcon a different parameter is altered for each level of the hierarchy: the first level of the tree (earcon family) is mapped to timbre; type is mapped to register; and function is mapped to rhythm. The complete earcon hierarchy is given as Table 2.

2.1.2. Register

Register, on its own, is not sufficient for earcon differentiation, and differentiation is key to their success [13]. However, in this scenario, register is never utilised as the only parameter in an earcon, therefore enabling it to provide a valuable variable in earcon differentiation. Previous study of register use in earcons [13] suggests that at least three octaves difference produces high recognition rates. It is also important to keep in mind the timbre being used, as some registers may not be suitable for a certain timbre. Two octaves separation between each register (Table 2) gives reasonable results.

Gesture Function	**Earcon Makeup**
Navigation:Browsing:Forward	Piano; Register a; Rhythm a
Navigation:Browsing:Back	Piano; Register a; Rhythm b
Navigation:Browsing:Home	Piano; Register a; Rhythm c
Navigation:Page Scroll:Up	Piano; Register b; Rhythm d
Navigation:Page Scroll:Down	Piano; Register b; Rhythm e
Navigation:Functions:New	Piano; Register c; Rhythm f
Navigation:Functions:Reload	Piano; Register c; Rhythm g
Navigation:Functions:Close	Piano; Register c; Rhythm h
Tabs:Browsing:Next Tab	Saxophone; Register a; Rhythm a
Tabs:Browsing:Previous Tab	Saxophone; Register a; Rhythm b
Tabs:Functions:New Tab	Saxophone; Register b; Rhythm f
Tabs:Functions:Duplicate Tab	Saxophone; Register b; Rhythm g
Images:Zoom In	Flute; Register a; Rhythm a
Images:Zoom Out	Flute; Register a; Rhythm b
Images:Hide	Flute; Register a; Rhythm i
Links:In New Window	Guitar; Register a; Rhythm j
Links:In New Tab	Guitar; Register a; Rhythm h

Register a begins at middle C, register b begins two octaves lower, and register c begins two octaves higher than register a. The rhythms can be seen in Fig. **??**

Table 2: Mapping of gestures to earcons

2.1.3. Rhythm

Rhythm is perhaps the most complex entity associated with the earcon. There are a number of parameters within it, which need to be altered in order to provide the most recognisable, and therefore effective, earcon design. First, as the defining factor in the duration of the final earcon the length of the rhythm must be established. The main consideration with regard to length is to ensure that the user can still proceed with their tasks without being hindered by the auditory feedback. This means that the feedback needs to be long enough for the user to be able to recognise it, but short enough that it does not encroach on the next task. A sample of existing earcons[1] reveals a mean duration of 1.75s. Not all the earcons in this sample were the same length, but to aid consistency in this experiment a length of between 1.5s and 2s was used.

The next factor is the number of tones in each rhythm. Guidelines state that rhythms can be made more recognisable by alternating the number of tones in each rhythm [13]. These guidelines were updated to show that an earcon should play no more than 6 notes in a 1 second period, and that very short note lengths would hinder recognition.

Another aspect of earcons, which is not specifically listed in the guidelines but has been identified in other studies is the use of musical metaphors. The functions which are being implemented with auditory feedback can be associated with metaphors which are then represented musically. For example, the backward navigation function can be represented by descending notes and the forward navigation by ascending notes. Functions such as "duplicate tab" can be represented by a repeating note pattern to represent the repetition of the tab. It is with these guidelines in mind that the rhythms identified as $a - j$ in Table 2 were designed. The scores for the full earcon set are given as Figs. 1 & 2.

Maasø [12] noted that feedback could be given on actions about to occur as well as ones that had already occurred. Thus Fig. 2 shows two extra earcons – one representing a legal action through a consonant sound, the other an illegal action through a dissonant sound – which offer pre-completion gesture feedback.

[1] see `http://www.dcs.gla.ac.uk/~mcgookdk/publications/2003/cdsoundsamples`

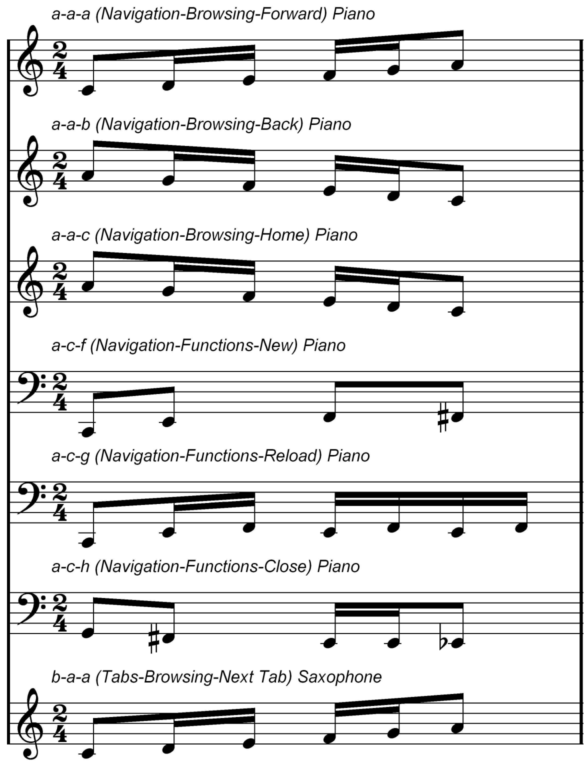

Figure 1: *Earcons 1-7*

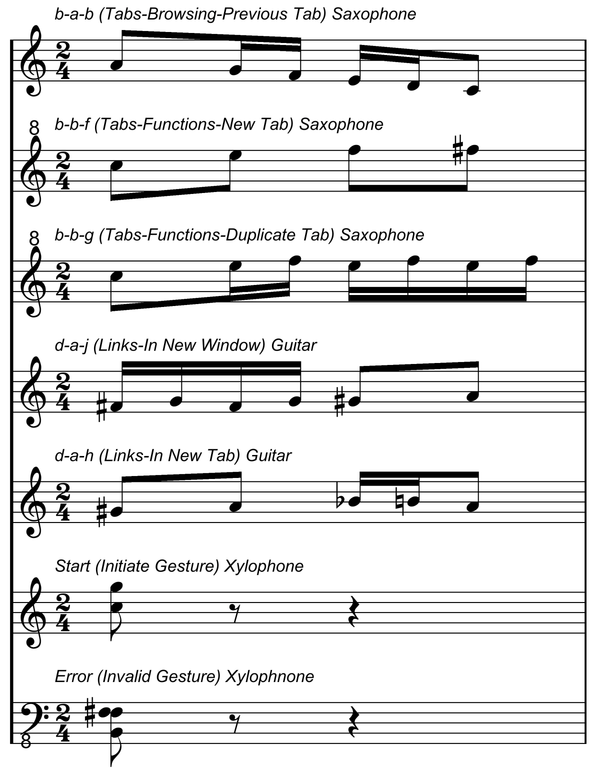

Figure 2: *Earcons 8-14*

In the non-sonified environment, when a gesture is made its validity is displayed textually in the browser's status bar. This requires the user to have visual attention on the page content, the gesture movements themselves, and the status bar all at once. This can cause problems when users are not even aware that they have commenced making a gesture. By signalling the beginning of a gesture with an earcon, the user can either continue or abort. Similarly, by signalling the invalidity of a gesture the user can abort it without wasting time on incorrect manoeuvres. These two earcons are unlike the hierarchical earcons designed for the gestures themselves as they need to be even shorter and unrelated (they do not belong to the hierarchy).

2.2. Sound Format

After considering the design of the earcons the next stage is to consider the format in which to implement them. The essential properties that are required are:

1. The ability to be embedded into FIREFOX.
2. Adequate sonic quality to ensure user recognition
3. Appropriate size for downloading – not such a major issue with the onset of broadband, but some users may still be using a dial-up connection.

There are several common formats which satisfy these requirements. The first property is the most important – the ability to be playable in FIREFOX. In order to embed sounds within the browser extension an audio plug-in must be configured to accept certain formats. Apple's QUICKTIME movie and audio player is the most commonly used with FIREFOX, therefore the audio format must be compatible with both FIREFOX and QUICKTIME.

QUICKTIME provides compatibility with the `.wav`, `.aiff`, `.au`, `MIDI` & `.mp3` formats. Of these, all except `MIDI` meet the requirements. The `.wav` format provides cross-platform compatibility and high audio fidelity and, because the earcons are short, the file sizes will also be small enough for download times not to be an issue.

2.3. Mouse gesture extension

With the current mouse gesture extension the user makes a movement with the mouse while holding down either the left or right mouse button (configurable by the user). This movement is classified into one of eight directions, as shown in Fig. 3. Once a movement has been made to start a gesture, the gesture recognition engine within the extension displays the recorded movements in the

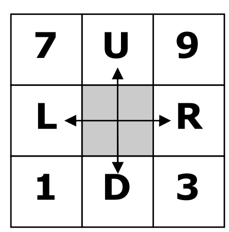

Figure 3: *Directions of mouse gesture movements in* FIREFOX

status bar of the browser. Once a valid gesture has been recognised and the mouse button is released, the extension invokes the corresponding browser command. The status bar shows the user if the gesture they are making is being recognised, if it is valid and briefly what the gesture made was. It is this visual feedback which has been found to be ineffective as the user mostly has their eyes focused on other areas of the screen. These steps are summarised below alongside the auditory feedback functions, to illustrate their position in the process.

1. User initiates gesture by holding mouse button and making a directional movement. **[Consonant earcon plays to show gesture has been started]**
2. Status bar displays message that gesture has been initiated.
3. Status bar displays directional movements of gesture so far
4. Gesture extension recognition engine records current movements and displays prediction of possible gesture in the status bar **[If invalid gesture is being made, dissonant earcon is played]**
5. User releases mouse button.
6. If the gesture is recognised, the extension calls the browser function to undertake required operation. The function performed is displayed in the status bar. **[Specific earcon relating to chosen function is played]**
7. If the gesture is not recognised a message is displayed in the status bar to show operation has been aborted. **[Dissonant earcon is played]**

2.4. Implementation

Adding the earcons to the existing FIREFOX gesture extension required a new JavaScript file to contain the audio functions which play the earcons. The existing JavaScript files were adapted to call the audio functions on gesture initiation, error and completion. In order to ensure the correct placement of feedback, auditory feedback was applied in the same code position as the visual feedback which is applied to the status bar of the web browser.

Following the implementation and an initial period of testing it was evident that some of the gestures were in themselves not functioning to an appropriate level in order to allow an effective experiment. Specifically the problem was with the image gestures and the page scrolling gestures. Both these sets of gestures were difficult to implement in the browser environment. As the purpose of this investigation is to discover if gestures are made more usable through the use of earcons, introducing gestures that are in essence already unusable would only hinder the study. Therefore the gestures for all image and page scroll functions have been excluded from this investigation. This leaves the experiment with 12 functions for testing – still enough for effective testing.

3. EVALUATION

Because the focus of this study was user satisfaction, it was decided to take a qualitative approach to the evaluation much like Moyle & Cockburn did in their assessment of user satisfaction with a browser's back button in the context of a gestural interaction environment [10]. Questionnaires of the type used by Moyle & Cockburn are an integral part of usability testing [14] and so were used in this study.

A questionnaire was designed to elicit user responses to the following issues:

1. The user is satisfied with the system
2. The user finds the system effective
3. The user finds the system efficient
4. The user can achieve all the tasks required
5. The user can easily learn tasks
6. The user can easily remember tasks
7. The user can recover from errors

In this list, elements 4 to 7 would be better suited to a quantitative research experiment. Therefore the results are indicative rather than statistically robust. The questions used in the study are given in Table 3 along with their average responses.

A multi-Phase study was conducted with eight users.

3.1. Phase 1 – The Training Environment #1 & Standard Mouse Gestures

The first stage of the experiment entailed the users familiarising themselves in a custom designed training environment[2] with the FIREFOX browser and the standard gestures (i.e. no auditory feedback).

3.2. Phase 2 – The Training Environment #2 & Auditory Mouse Gestures

This second training stage introduced the users to the auditory gestures. Time was given for free practice before the next Phase.

3.3. Phase 3 – Main Study #1

After the training sessions users followed a prescribed script which led them through a number of navigational manoeuvres using the gestures. This stage was carried out with the computer's sound muted to remove the auditory aspect of the gestures. Once the tasks had been completed section 1 of the questionnaire was answered (see Table 3 – Phase 3 questions).

3.4. Phase 4 – Main Study #2

In Phase 4 another prescribed set of manoeuvres was followed, this time with the earcons being made audible; the script was different from the one in Phase 3, but the same gesture functions were used. Upon completion, section 2 of the questionnaire was completed (see Table 3 – Phase 4 questions).

3.5. Phase 5 – Standard Mouse Gestures

The final stage of the experiment required users to return to using the standard mouse gestures. This acts as a control to rule out possible learning effects being implicated in any possible increase in user satisfaction. Following the set tasks users were also asked to comment on using the mouse gestures without sound after having used them with sound (see Table 3 – Phase 5 questions). This gave the users an increased opportunity to reflect on the effectiveness of the auditory gestures.

[2] The training environment can be found at `www.louise-midgley.org/test/`

3.6. NASA TLX

After each Phase of the experiment users completed a set of NASA-TLX (Task Load Index) [15, 16] rating sheets in order to assess the workload experienced:

> The NASA Task Load Index is a multi-dimensional rating procedure that provides an overall workload score [*out of 100*] based on a weighted average of ratings on six subscales: Mental Demands, Physical Demands, Temporal Demands, Own Performance, Effort, and Frustration [15].

4. RESULTS

4.1. Workload

An overall reduction in users' workload was reported over the three experimental task Phases (Phase 3 $\mu = 56$, Phase 4 $\mu = 47$, Phase 5 $\mu = 46$), the largest drop being between Phase 3 and Phase 4. The workload factors with the greatest contribution to the overall score were *mental demand* and *performance*. Whilst the workload was observed to fall, it is not clear whether this was due to increase familiarity with gestural interaction as the experiment proceeded. The larger drop between Phase 3 and Phase 4 may indicate that the earcons assisted in reducing the workload, though more studies would be needed to explore this issue.

4.2. Phase 3

The average results from the Phase 3 questionnaire are given in Table 3. They show that the participants found the standard mouse gestures offered an effective and efficient aid to web navigation. There was no solid opinion on the reduction of errors or recall and learnability. There was also no opinion offered on the use of auditory feedback – an expected result. The results of these questions help us build a picture for the basis of the experiment – the participants find standard mouse gestures a useful addition to their web browser and have no bias towards or against auditory feedback. These results will allow the measurement of the effect that the auditory feedback has on the participant.

4.3. Phase 4

The questionnaire results for Phase 4 (Table 3) show that participants favoured the auditory gestures. Participants found the auditory gestures enabled web browsing to be more efficient, slightly quicker and made fewer errors. They didn't find the auditory gestures any easier to learn or recall than the standard mouse gestures. These positive results will be tested by the results found in Phase 3.

The results also complement those that were discussed previously which stemmed from the workload analysis. The TLX results showed a lower workload score, with further analysis indicating this was due mainly to a feeling of lower frustration and pressure on achieving goals. The comments which were included by the participants at the end of Phase 3 also indicated that frustration may be a factor which hinders use of the standard mouse gestures. The feedback indicated that the participants found the auditory feedback enabled them to be more aware of the mistakes they were making, and therefore more able to recover from them. This could be a factor for the decrease in frustration but there is no clear link, so again it is just a conjecture. Other comments from

Question	Average Score (1-5)
Phase 3	
1. *The standard mouse gestures provide an effective aid to web browsing* (Strongly Disagree [1] … Strongly Agree [5])	4
2. *The standard mouse gestures allowed me to quickly navigate web pages* (Strongly Disagree [1]… Strongly Agree [5])	4
3. *I was able to complete all the tasks with minimal errors* (Strongly Disagree [1]… Strongly Agree [5])	3
4. *The gesture system was easy to learn and recall* (Strongly Disagree [1] … Strongly Agree [5])	3
5. *Auditory feedback will allow me to use the gestures more efficiently* (Strongly Disagree [1] … Strongly Agree [5])	3
Phase 4	
1. *The auditory mouse gestures provide a more effective aid to web browsing than standard mouse gestures* (More Effective [1] … Less Effective [5]	2
2. *The auditory mouse gestures allowed me to navigate quicker than the standard mouse gestures* (Quicker [1] … Slower [5])	2.5
3. *I was able to complete all the tasks with fewer errors than when using standard mouse gestures* (Fewer Errors [1] … More Errors [5])	2
4. *The auditory gesture system was easier to learn and recall than the standard mouse gesture system* (Easy to Learn [1] … Hard to Learn [5])	3
5. *I prefer auditory gestures to standard gestures* (Auditory Gestures [1] … Standard Gestures [5])	2
Phase 5	
1. *Standard mouse gestures provide a more effective aid to web browsing than auditory mouse gestures* (More Effective [1] … Less Effective [5]	4
2. *Standard mouse gestures allowed me to navigate quicker than the auditory mouse gestures* (Quicker [1] … Slower [5])	3.5
3. *I was able to complete all the tasks with fewer errors than when using the auditory mouse gestures* (Fewer Errors [1] … More Errors [5])	3
4. *The standard gesture system was easier to learn and recall than the auditory mouse gesture system* (Easy to Learn [1] … Hard to Learn [5])	3
5. *I prefer standard gestures to auditory gestures* (Standard Gestures [1] … Auditory Gestures [5])	4

Table 3: Results of questionnaires for Phases 3, 4, & 5

participants show that the auditory gestures were more difficult to learn, which would be the expected outcome, and that even though they were useful they didn't speed up the browsing process. These results slightly differ from the average responses seen on the main questionnaire showing that the results are not conclusive and limitations do exist. These limitations will be discussed later in the study.

4.4. Phase 5

The Phase 5 questionnaire (Table 3) was a mirror of those asked in the previous Phase to test if the participant changed their mind regarding the auditory gestures once they were reintroduced to the standard gesture system. Apart from question 3, the results exactly mirror those of the previous Phase. The only result that changes is regarding errors; the participants have changed their mind and decided that there is no difference in errors between the standard and auditory mouse gestures. This could be because they are more aware of the gestures they are now making due to the increased practice they have had, or a genuine realisation that errors are no different now that they are back with the standard gesture system. Referring back to the results of the workload analysis, at this point it was identified that overall workload stayed about the same between Phases 2 and 3, although some of the contributors fluctuated.

The increase in frustration and performance can be connected with some of the participant comments. The participants stated that they missed the feedback which enabled them to recover from errors, and that the auditory feedback made the gestures easier to use. This could have led to an increase in frustration and reduced the feeling of achieving an adequate level of performance.

4.5. Opinion vs workload

Table 4 shows how the participants 'voted' for the different types of gestures and the associated workload of the Phase. It is interesting to note the differences between the workload, and that a lower workload score does not mean that the gesture type being used is favoured. Examining participant 5, who had no preference over both Phases, it is seen that the workload increases for Phase 3, but the participant still identifies no preference. This participant does not have the highest workload in Phase 2, but still identifies that the auditory gestures are equal in relevance to the standard system. The workload is subjective, and while it helps to clarify the position of a participant it is not alone an effective measure.

	Phase 4		**Phase 5**	
Participant	Preference	Workload	Preference	Workload
1	Auditory	53	Auditory	49
2	Auditory	44	Auditory	43
3	Auditory	57	Auditory	47
4	Auditory	48	Auditory	63
5	None	40	None	47
6	Auditory	55	Auditory	56
7	None	54	Auditory	50
8	Auditory	22	Auditory	13

Table 4: User preferences and workload in Phases 4 & 5

Complete results and a fuller discussion are given in [17].

5. SUMMARY

The results from this study can be discussed in the light of earlier work. The results are in line with those found by Pirhonen et al [6] in their study of a music player which offers auditory feedback. They concluded that gestures which are followed by auditory feedback are learnt more rapidly. This study points that this may be the case – although none of the evidence is conclusive, it does head in the same direction.

Akamatsu et al [18] argued that visual dependency is reduced, and overall performance is increased when other senses, such as auditory, are used within an interface. This study shows that the auditory feedback allows users to be more aware of the visual situation. Although no actual testing was done on the effect of the visual feedback in the status bar, the auditory feedback was a clear success and one of the reasons for it was that it enabled the participants to concentrate on what they were doing visually, while also being aware of their position and validity of their moves through an auditory interface.

The study most closely linked to this one is that of Moyle & Cockburn [10]. Their study concludes that gestures increase the efficiency of navigation in a web browser. It can be seen that what has been investigated here with the auditory gestures is an extension of the Moyle & Cockburn study, and offers a further improvement on their navigational gestures.

Although none of the evidence is conclusive the trends are consistent with the notion that the usability of standard mouse gestures (as measured by user satisfaction) can be increased by adding auditory feedback.

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